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(Hebrew)
(באנגלית)
A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS (English)

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ABSTARCT OF THE INVENTION

The present invention discloses a method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

In both print head constructions there are nozzles positioned in the inner parts of the print head, or closer to the center of the print head and peripheral nozzles, which are closer to the edges of the print head.

APPLICATION FOR PATENT

Title: A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS

FIELD OF THE INVENTION

[0001] The present invention relates to the field of inkjet printing and particularly to printing on large format flexible substrates.

BACKGROUND OF THE INVENTION

[0002] Inkjet printing has gained popularity in a number of applications. One of the growing printing applications is printing of billboards, banners and point of sale displays. The ink-jet printing process involves manipulation of drops of ink ejected from an orifice or a number of orifices of a print head onto an adjacent print substrate. Paper, vinyl, textiles, fabrics, and others are examples of print substrates. An ink-jet print head consists of an array or a matrix of ink nozzles, with each nozzle selectively ejecting ink droplets. In both print head constructions the ink ejecting nozzles are usually equidistantly distributed along the width (length) of the print head. A given nozzle of the print head ejects the droplet in a predefined print position on the substrate. An assembly of the adjacently positioned on the substrate ink droplets creates a predetermined print pattern or image. Relative movement between the substrate and the print head enables substrate coverage and image creation. Each ink droplet comprises a picture element, or "pixel." Good print quality requires printing resolution higher that 600 pixel per inch. A typical pitch of an array of nozzles is however 180 or less nozzles per inch.

[0003] To produce the relative movement enabling image creation the substrate moves in one direction termed first direction, and print head moves in another direction termed second direction. The second direction is usually orthogonal to the first direction. Generally, the print head has less weight and is much smaller in size than substrate. It is convenient to move print head fast over the substrate in a type of reciprocating movement. Each successive reciprocating scan by such a print head in

the second direction creates a relatively wide ink-marked strip or printed swath. The substrate is advancing periodically or simultaneously in the second direction.

[0004] In order to cover the substrate with the desired print resolution of for example 720 pixel per inch a single print head with nozzle pitch of 180 nozzles per inch has to scan in a reciprocating type of movement the print swath four times. Each scan is may be distant from the previous one on 1/720 of inch. The data to be printed is divided accordingly between the scans. This type of printing is called multi pass printing mode. Alternatively for printing at 720 pixels per inch resolution four print heads with nozzle pitch of 180 nozzles per inch may be organized on a common mechanical structure shifted one with respect to the other on a 1/720 of an inch. Organized in this manner print heads may print the desired image in a single pass printing mode, providing better ink coverage and creating more vivid colors. The cost of such print head structure is however too high for regular commercial use. Common structures with print heads shifted one with respect to the other on a fraction of a print head dimension (staggered) are also known in the art.

[0005] Recently inkjet print heads such as XAAR Leopard having nozzle pitch of 300 nozzles per inch and commercially available from XAAR Plc., Cambridge, UK and MAGIC having nozzle pitch of 600 nozzles per inch and commercially available from Scitex Vision Ltd., Netanya, Israel have appeared on the market. Although these print heads have nozzle pitch suitable for high quality printing the printing itself is performed in multi-pass mode. Printing in such cases is performed at full print head resolution but the amount of data to be printed is distributed between the successive print scans. Such multi pass printing method contributes to print quality and provides a better redundancy, since different nozzles participate in printing sections of the same line.

[0006] In order to print an image in multi pass printing the substrate is usually advanced on a multiple of print resolution. The multiple of the print resolution may be smaller or larger than one. This relatively small incremental movement continues until the whole image is printed and requires high position accuracy, which is generally hard or even impossible to achieve by the movement of the large and flexible substrate. Errors in butting such two successive print head scans result in micro

banding effects called printing artifacts. In single pass printing each successive movement of the print head in the second printing direction prints a swath of color equal in width to the print head width. Errors in butting two successive print head wide or print structure wide swaths result in macro banding, which is also called printing artifact. In both cases the butting of two successive image swaths should be perfect, since human eye is extremely sensitive to printing artifacts caused by errors in relative positioning of the print head and substrate. (For the simplicity of explanation the term "print head" will be used for both single print head and a plurality or print heads organized on a common mechanical structure.)

[0007] There are known in the art constructions of ink jet printing machines that have a drum or a table on which the substrate is placed for printing. The accuracy of the relative movement between a rigid drum or table holding the substrate and the print head that moves on linear guides is relatively good and creates small image artifacts. These printers have however, a very large footprint, are expensive and difficult to maintain. A significant number of wide format printing applications, however is done on flexible substrate. Special printing machines termed Roll-to-Roll (R2R) printing machines, are typically used for printing on such substrates. Because the substrate has no support structures these machines have small footprint and high-speed operation. The R2R machines print on five-meter wide flexible substrates. One of the drawbacks of the Roll-to-Roll printing machines is the low accuracy of the relative movement between such a wide flexible substrate and the print head.

[0008] Figure 1 illustrates a typical Roll-to-Roll (R2R) printing machine. The machine has a substrate supply roll **100**, a substrate-collecting roll **102**, and a print head **106**. Rotation of substrate collecting roll **102** pulls substrate **108** of substrate supply roll **100** and moves it in a first printing direction indicated by arrow **110**. Print head **106** reciprocally moves in a second printing direction indicated by arrow **112**. The second printing direction is generally orthogonal to the first printing direction. Mechanism enabling print head **106** reciprocating movement in the second direction indicated by arrow **112** may be a linear motor with a guide **116**, or a metal band or linear guides with a screw drive. A regular motor (not shown) or a motor with a gear may drive substrate-collecting roll **102**. Control computer **114** controls operation of print head **106** and the printer.

[0009] Perfect swath butting, especially in multi pass printing is difficult to achieve on R2R printers. When pooled/moved flexible substrate easy stretches and deforms and accordingly changes its dimensions. This makes small, comparable with the printing resolution incremental movement of flexible substrate with accuracy of few microns nearly impossible.

[0010] Printing of large size images on wide flexible substrates requires not only global dimensions accuracy; it requires multiple local position corrections that compensate for errors in the image printed. Errors caused by wide flexible substrate distortion. These corrections cannot be properly made by the use of encoders. Because of substrate flexibility neither linear nor rotary encoders do not represent accurately the substrate position. There are however, no known methods of other than encoder signal derived information for local image correction.

[0011] The inventors of the present invention are also not aware of any known methods of local image correction that account for actual image on substrate position.

SUMMARY OF THE INVENTION

[0012] There is therefore a need in the industry to provide a method of printing on wide format flexible substrates free of the described above problems.

[0013] There is an additional need to improve the quality of the printed image by accurately butting successive swaths and swath filling scans of printed image in multi pass printing mode.

[0014] There is a further need in the industry to provide a low cost method of image printing capable of providing accurate local printed image position correction and reducing printing artifacts. A low cost method of image printing that accounts for actual image or substrate position.

[0015] Generally, these objectives may be achieved by a method of multi pass inkjet printing on wide format flexible substrates where printing image artifacts cased by

errors (deformations) in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry and position of the adjacent earlier printed image swath.

[0016] Exemplary embodiments of the present invention are directed to a method and apparatus that compensates for errors in the image position caused by deformations of wide format flexible substrate movement by printing with a smaller amount of nozzles than supported by the print head and using the non-operative nozzles for substrate position error correction. This is achieved by splitting virtually the print head on inner section of nozzles and peripheral section of nozzles and controlling an ink jet print head drop ejection nozzle position as function of the actual printed image on substrate position. The control of the drop ejecting nozzle position is achieved by shifting data to be printed between the inner and peripheral nozzles of the print head. The shift of data between inner and peripheral nozzles takes place during the multi pass printing process. Proper activation and positioning of the drop ejecting nozzle compensates for errors in the image on substrate position caused by wide format substrate movement deformations and reduces or eliminates micro and macro-banding effects causing printed image artifacts.

[0017] According to one exemplary embodiment the objectives of the present invention are achieved by replacing the small incremental wide format flexible substrate movement in the first direction by shift of the data to be printed between the inner and peripheral nozzles of the print head. The shift of data between inner and peripheral nozzles of the print head provides an image position shift in the first direction. Filling the printed swath by reciprocating scanning movement of the print head in second direction and moving the substrate in the first printing direction in swath wide steps. The magnitude of the data shift between the two sections of nozzles is equivalent to small incremental movement or stepping of the substrate in the first direction and is a function of nozzle pitch (**P**) distance and printing resolution (**R**).

[0018] In accordance with this embodiment the objectives of the present invention may be achieved by a method of inkjet printing on wide format flexible substrates, comprising steps of: providing an inkjet printer having a print head, a substrate, and a control computer; moving the substrate in the first printing direction and scanning the

substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction, the print head having further its nozzles split virtually on inner section of nozzles and peripheral section of nozzles and having capability of shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections; the data shift being equivalent to the image shift in the first printing direction; printing an image on the substrate by swaths generally narrower than print head width (**W**); filling the printed swath by reciprocating scanning movement of the print head in the second direction and shifting the data to be printed between the inner nozzle sections and peripheral nozzle sections on a multiple of print resolution (**R**) in the first scanning direction (back and forth); moving the substrate in swath wide steps in first printing direction and where the control computer distributes the movement in the first direction between the substrate and the shift of data provided to the print head.

[0019] According to another exemplary embodiment the objectives of the present invention may be achieved by advancing the wide format flexible substrate on a small incremental step and printing simultaneously with the image certain image position control marks. Image position control marks may be printed (located) on image free areas of the substrate. Alternatively image position control marks may be printed (located) within the image or on the image area. Image position control marks may be printed by visible or invisible to human eye ink. Coordinates of the image position control marks printed simultaneously with the image define the actual position of the printed image on the substrate and the substrate itself.

[0020] Image position detectors detect image position control marks coordinates and communicate these coordinates to the control computer. The substrate typically moves in first printing direction only. Print head, which generally moves in second printing direction, has its nozzles virtually split on inner section of nozzles and peripheral section of nozzles and has further capability of shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections. The substrate movement error compensation is performed by shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections of print head in the first printing direction simultaneously with the movement of the print head in the second direction. Control computer calculates the error compensation value by

comparing the actual image position with the desired or target image position. Control computer generates appropriate correction signal that causes a shift of the data to be printed (back and forth) between the inner and peripheral nozzle sections of the print head.

[0021] In accordance with this embodiment the objectives of the present invention may be achieved by a method of inkjet printing on wide format flexible substrates, comprising steps of: providing an inkjet printer having a print head, a substrate, image position detecting means, and a control computer; moving the substrate in the first printing direction and scanning the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction, the print head has its nozzles virtually split on inner section of nozzles and peripheral section of nozzles and has further capability of shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections in the first printing direction; printing simultaneously with the image a series of image position control marks, which define actual image on the substrate position; detecting by substrate position detecting means the control marks coordinates and providing the control marks coordinates to the control computer; calculating the image position deviation value from the desired image position and wherein the ink jet printing is performed by correcting the image position error by shifting the data to be printed between the inner section of nozzles and peripheral nozzle section; the shift of data being equivalent to image movement in the first direction in accordance with the image position deviation value calculated by the control computer.

[0022] The substrate position error is corrected by shifting data to be printed between the inner section of nozzles and peripheral section of nozzles in the first printing direction on a step matching the error (deviation) in image position. The shift of the data to be printed between the inner section of nozzles and peripheral section of nozzles may be performed concurrently and continuously with the printed swath-filling scan.

[0023] The method of wide format inkjet printing on flexible substrate that derives the printing position based on the printed image position or on the position of digitally

introduced image position control elements. Specially introduced printed marks may serve as image on substrate position control marks or elements.

[0024] Image position control marks may be printed (located) on image free areas of the substrate. Alternatively image position control marks may be printed on the areas of the substrate occupied by the image. Image position control marks may be printed by invisible or visible to the human eye ink.

[0025] According to a further exemplary embodiment the objectives of the present invention may be achieved by continuously monitoring the advance of the wide format flexible substrate and correcting image position by shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections of the print head. The substrate movement error compensation is performed by shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections of print head in the first printing direction simultaneously with the movement of the print head in the second direction. Control computer calculates the error compensation value by comparing the actual substrate position with the desired or target substrate position. Control computer generates appropriate correction signal that causes associated with it shift of the data to be printed (back and forth) between the inner and peripheral nozzle sections of the print head.

[0026] Continuous monitoring of the substrate advance and position may be performed by non-contact or contact substrate advance and position monitoring means. Non-contact means may be optical mouse type sensors or other similar sensors. Contact means may be simple metering rolls that are in contact with the substrate.

[0027] According to one exemplary embodiment the printing method of the present invention is enabled by an inkjet printing apparatus for printing on wide format flexible substrates, comprising: a substrate and a mechanism for moving the substrate, a print head having its nozzles split on an inner section nozzles and peripheral section nozzles and being capable of shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head, image position detecting means, and a control computer; the substrate moving mechanism moves the substrate

in the first printing direction and the print head moving mechanism scans the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction; the print head has further its nozzles virtually split on an inner section nozzles and peripheral section nozzles and being capable of shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head (back and forth); the print head prints simultaneously an image and a series of image position control marks, coordinates of the image position control marks provide information on actual image position; the image position detecting means, detect the image position control marks coordinates and communicate the coordinates to the control computer; the control computer calculates the deviation of the actual image position from the desired (target) image position, and whereby the inkjet printing is performed by correcting the image position error along the second printing direction by shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head in the first printing direction in accordance with the image position deviation value .

[0028] An inkjet printing apparatus for printing on wide format flexible substrates where image position control marks may be printed by ink invisible or visible to human eyes.

[0029] The shift of data to be printed between the inner section nozzles and peripheral section nozzles of the print head is equivalent to image shift in the first printing direction on a value matching the image position deviation value compensates for the substrate position error.

[0030] An inkjet printing apparatus for printing on wide format flexible substrates where image position detection means are one of a group of photodiode, quadrant detector, solar element, CCD, or video camera.

[0031] An inkjet printing apparatus for printing on wide format flexible substrates where a control computer processes the image position deviation value describing the deviation of the actual printed image swath position from the desired (target) image swath position and generates a signal for shifting the data between the inner section of nozzles and the peripheral section of nozzles of the print head.

[0032] According to another exemplary embodiment the printing method of the present invention is enabled by an inkjet printing apparatus for printing on wide format flexible substrates, comprising: a substrate and a mechanism for moving the substrate, a print head having its nozzles split on an inner section nozzles and peripheral section nozzles and being capable of shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head, substrate position detecting means, and a control computer; the substrate moving mechanism moves the substrate in the first printing direction and the print head moving mechanism scans the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction; the print head further has its nozzles virtually split on an inner section nozzles and peripheral section nozzles and being capable of shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head it in the first printing direction (back and forth); substrate position detecting means continuously monitor substrate position, and communicate the position to the control computer; the control computer calculates the deviation of the actual substrate position from the desired (target) substrate position, and whereby the inkjet printing is performed by correcting the substrate position error along the second printing direction by shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head in the first printing direction in accordance with the image position deviation value .

[0033] The shift of data to be printed between the inner section nozzles and peripheral section nozzles of the print head is equivalent to image shift in the first printing direction on a value matching the substrate position deviation value compensates for the substrate position error.

[0034] An inkjet printing apparatus for printing on wide format flexible substrates where non-contact substrate position detection means are optical mouse type sensors or other similar sensors.

[0035] An inkjet printing apparatus for printing on wide format flexible substrates where substrate position detection means are contact means such as metering rolls that are in contact with the substrate.

[0036] An inkjet printing apparatus for printing on wide format flexible substrates where a control computer processes the image position deviation value describing the deviation of the actual substrate position from the desired (target) substrate position and generates a signal for shifting the data between the inner section of nozzles and the peripheral section of nozzles of the print head.

[0037] The advantage of the method is that it reduces the swaths macro and micro banding effects and adapts the geometry of the image to the actual position of the previous swath reducing the undesired visual effects (printing artifacts) caused by deformations in substrate size during substrate movement.

[0038] A further advantage of the method is that it does not make use of auxiliary substrate supports such as drum, table, endless metal bands or precisely formed surface reducing by this the manufacturing cost of the printing apparatus.

[0039] It is an additional advantage of the method disclosed that the printing position information is derived from the previously printed image position or actual substrate position without the use of costly auxiliary position monitoring devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] The foregoing and other objects, features and advantages of the invention will be apparent from the more particular description of the exemplary embodiments of the invention, as illustrated in the accompanying drawings in which like reference numbers refer to the same parts throughout the different figures. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0041] Figure 1 is a schematic representation of a simplified prior art roll-to-roll inkjet printer;

[0042] Figures 2A and 2B are schematic illustration of an inkjet printer and a swath of an image printed by prior art multi pass printing method;

[0043] Figures 3 is schematic illustration of additional prior art multi pass image printing methods;

[0044] Figures 4A and 4B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with one of the exemplary embodiments of the present invention;

[0045] Figures 5A and 5B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with another exemplary embodiment of the present invention;

[0046] Figure 6 is a simplified flow chart of image on substrate position control marks placement decision making algorithm;

[0047] Figures 7A and 7B are schematic illustrations of an inkjet printer constructed in accordance with an additional exemplary embodiment of the present invention;

[0048] Figure 8 is a detailed schematic illustrations of contact substrate position monitoring means constructed in accordance with the present invention;

DETAILED DESCRIPTION OF THE INVENTION

[0049] The principles and execution of a method according to the present invention, and the operation and properties of an ink jet printing apparatus enabling the printing method may be understood with reference to the drawings and the accompanying description of non-limiting, exemplary embodiments.

[0050] Reference is now made to Figures 2A and 2B which are schematic illustrations of a prior art printer and a prior art multi pass printing method. Print head **120** is printing an image consisting of a number of swaths and in particular print swath of the image bounded by lines of rectangle **122**. Print head nozzle pitch **P** is lower than the

required print resolution **R** and in order to fill print swath bounded by lines of rectangle **122** the printing is performed in a multi pass mode. For the simplicity of explanation the printing resolution **R** is equal in both first and second directions. Substrate **108** is advanced in the first direction indicated by arrow **110.** When print head **120** scans in the second direction indicated by arrow **124** each of print head **120** nozzles **126** prints respective line shown as separate square pixels **130a**. Numeral **122'** (Fig. 2B) marks new swath boundaries. At the end of the scan substrate **108** is incrementally advanced in the first direction (first printing direction) indicated by arrow **110**, print head **120** moves back (reciprocating type of movement) in the direction indicated by arrow **146** (Fig. 2B) and each of the nozzles **126** prints respective print line shown as separate square pixels **130b**. The process continues until the swath bounded by lines of rectangle **122** is filled in. (The previous scan is shown in lines and characters having lower density.)

[0051] As illustrated in Fig. 2B the incremental advance of substrate **108** having large dimensions and being flexible is not equal along print head scan path. When pulled or moved by other means, wide size flexible substrate **108** stretches or skews and undergoes other types of distortions. These stretches and skews create visually disturbing micro banding effects (printing artifacts) shown in Figure 2B. (The printed image should have homogeneous structure and be free form visible micro and macro banding effects or artifacts.) Other numerals on Figures 2A and 2B indicate: **136** and **138** are motors that provide movement to substrate-collecting roll **102**, and print head **120** respectively; **140** is a linear guide on which print head **120** travels (scans) forth and back; **122'** designates lines of rectangle that bounds print swath printed by print head **120** when it moves back (reciprocating type of movement) in the direction indicated by arrow **146.**

[0052] Figures 2A and 2B illustrate a certain type of printed swath filling pattern in a multi pass printing mode. Some additional prior art technique for printed swath filling patterns in a multi pass printing mode is illustrated in Figure 3. Figure 3 shows a possible multi pass printing method with a print head **132** having nozzles **134** pitch **P** equal to the printing resolution **R**. Two passes are required to fill-in printed swath bounded by lines **150**. The data to be printed may be equally distributed between the passes. Such multi pass printing method contributes to print quality and provides a

higher redundancy level, since different nozzles participate in printing the same line when scanning the substrate in a reciprocating type of movement. The swath width and swath-filling rate were introduced for exemplary purposes only and other ratios are possible.

[0053] Present invention discloses a method and an apparatus for ink jet printing on wide format flexible substrates that reduces visually disturbing micro banding errors caused by deformations, stretches and skews of the wide format flexible substrate. Figure 4A is an illustration of an inkjet printer constructed in accordance with one of the embodiments of the present invention and a swath of a printed image printed by the printer of the present invention. Ink ejecting nozzles distributed along print head **174** width (W) are split virtually into inner section nozzles **(IN)** and peripheral section nozzles **(PER)**. Not like in the existing prior art inkjet printers for the purpose of filling in printed swath **176** shift of the data from inner section nozzles **(IN)** to peripheral section nozzles **(PER)** of print head **174** replaces the small incremental advance of flexible substrate **108**. Shift of the data between inner nozzles **(IN)** to peripheral nozzles **(PER)** of print head **174** is equivalent to printed image shift in the first direction indicated by arrow **170**. Direction **170** is generally parallel with first direction indicated by arrow **110**. (Figure 4 shows direction **170** of shift of the data between inner nozzles to peripheral nozzles of print head as a vertical one. It is necessary to mention that the method is applicable to any print head position and to any shift direction.)

[0054] Print head moving mechanism moves print head **174** in the direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement nozzles **184** of print head **174** eject ink droplets and print a swath bounded by lines of rectangle **176**. Each nozzle **184** preferably of the inner nozzles section of print head **174** prints a line of pixels **178a**. The printing is performed in multi pass mode. In accordance with the present invention for the purpose of filling in printed swath **176** shift of the data between inner section nozzles to peripheral section nozzles of print head **174** in the first direction replaces the small incremental advance of flexible substrate **108**. Figure 4B shows printing of the next swath-filling scan. When print head makes the next scan moving in the direction of arrow **146** it prints pixels **178b**. For printing pixel(s) **178b** the data was shifted from

the inner section nozzles (**IN**) to the lower peripheral section nozzles (**PER**) of print head **174**. Numeral **210** introduced for illustrative purposes only, marks the shift. Substrate **108** remains stationary during the swath filling process. The multi pass swath-filling pattern has been shown for exemplary purposes only. Other swath filling patterns are possible. (Due to imperfections of the drawing software some artifacts may be present on the drawing.)

[0055] Following completion of swath filling wide flexible substrate **108** advances on swath width (W) in the first direction and positions substrate 108 in a position for next swath do be printed. The distribution of the movement in the first direction between the shift of nozzles of print head **174** and wide flexible substrate **108** advance significantly reduces micro banding effects and associated with them printing artifacts. Control computer **114** controls the shift of data between the nozzles of print head **174** and the distribution of the movements in the first direction between the shift (of data) between the nozzles of print head **174** and substrate **108**.

[0056] In accordance with another exemplary embodiment shown in Figure 5A inkjet printing apparatus of the present invention in addition to print head **174** having its nozzles split virtually on inner section nozzles and peripheral section nozzles has image position detecting means **180**. Image position detection means **180** may be located along the second printing direction. Generally, image position detection means **180** should be of extended form to cover the whole width of printing substrate **108**. Alternatively image position detection means **180** may be positioned at predefined locations over substrate **108**. Their position may be fixed or adjustable as appropriate for a particular machine design. Image position detection means **180** include a source of illumination and a detector. The source of illumination may be an incandescent lamp, a LED or a laser diode operating in visible or non-visible range of spectrum. The detector may be a photodiode, a quadrant detector, a CCD, or a video camera type detector. Control computer **114** controls operation of all units of the printer.

[0057] For printing, substrate-moving mechanism moves substrate **108** in first printing direction indicated by arrow **110**. Print head moving mechanism moves print head **174** in the direction indicated by arrow **124** from one edge of substrate **108** to the

second edge of substrate **108**. In course of this movement print head **174** ejects ink droplets and prints a swath bounded by lines of rectangle **190**. The printing is performed in multi pass mode. In accordance with the present invention concurrently to printing a print swath of an image print head **120** prints in predefined positions image position control marks **200**.

[0058] Control marks **200** may be printed on image free areas of the substrate or on areas of the substrate occupied by an image. When control marks 200 are printed on image free areas or on the edges of the substrate the shift between the inner and peripheral nozzle sections is some how less accurate, since the correction shift of the data is calculated based on the coordinates of two, located at the edges of the image, points only. Control marks **200** may be printed by ink visible to human eye or invisible to human eye.

[0059] Following each successive swath print, wide flexible substrate **108** advances on the required small distance in the first direction. This advance of wide flexible substrate **108** is not an accurate one, since deformations introduced into wide flexible substrate are not homogeneous across the width of substrate. In order to compensate for deficiencies of substrate moving mechanism, resulting in micro banding, image on substrate position detecting means **180** detect and measure the coordinates of image position control marks **200**.

[0060] Substrate position detecting means **180** communicate the coordinates of image position control marks **200** to control computer **114**. Image position control marks **200** are indicators of the actual image position (and the position of substrate itself). Control computer **114** uses the coordinates of image position control marks **200** to calculate the deviation of the actual image or pixel position from the target or desired image position. Control computer **114** calculates the required correction data shift between the inner and peripheral nozzles of print head **174** with respect to the previously printed swath.

[0061] In accordance with the present invention in course of print head **174** movement in the second direction indicated by arrow **146** (Fig. 5B) continuous corrective data shift between inner and peripheral sections of nozzles takes place. The

shift creates printed image movement, which is generally parallel to first printing direction **110**. The continuous corrective data shift compensates for deformations and an error caused by wide format flexible substrate movement and reduces visible micro banding effects. Figure 5B shows that when print head makes the next scan moving in the direction of arrow **146** and printing pixels **192b** the data shift has involved in printing one peripheral nozzle **(PER)** at the beginning of the scan and on two peripheral nozzles at the end of the scan. Allover data shift was two nozzles and the printed image position was shift accordingly.

[0062] In practice the method of multi pass inkjet printing on wide format flexible substrates adapts the geometry and position of the next printed swath to the geometry and position of the adjacent earlier printed image swath.

[0063] As illustrated in figures 2B and 5B wide flexible substrates do not deform in a homogeneous way along their width or length and some areas of the printed image may have deformations larger than the other. In order to correct the micro and macro printed swath butting errors caused by the non-homogeneous deformation of wide format flexible substrate along the printed swath image position control marks should be located along and across a printed swath enabling dynamic print head position correction. Image position control marks **200** may have any shape suitable for machine detection and convenient for deriving based on the image on substrate position detector readings the actual new position of flexible substrate **108**. The size of image on substrate position control marks **200** is selected to enable reliable position detection without affecting image quality or content.

[0064] Figure 5B illustrates an exemplary placement and form of image position control marks **200** along and across printed swath **190** and **190'**. When position control marks **200** are located along and across printed swath i.e., within the printed image itself their size and color should be selected in way that does not created undesired visual effects. Alternatively image position control marks **200** may be printed by invisible to human eye ink.

[0065] Digital image analysis precedes or is made concurrently with the swath printing process. The purpose of the analysis is to define proper position locations of

image position control marks **200** along and across printed swath **190**. Figure 6 shows a simplified image position control marks **200** position locations algorithm. Initially, (step **230**) the digital image to be printed is partitioned into printed swaths and strips of image pertaining to the same swath are defined. Printing is usually performed in four process colors cyan, magenta, yellow and black (CMYK). The proportion of each of the process colors within each of the swaths is different and at step **232** ink coverage or content for a particular printed swath is calculated for each ink. Image position control marks **200** are preferably printed by a color (ink) that has largest coverage (proportion) in a particular swath. This ink is selected at step **234**. Further to this image on substrate position control marks printed when print head moves in the direction indicated by arrow **124** are preferably placed in places that will be overprinted by ink of the same color when print head **120** will move in the direction indicated by arrow **146**. In order to find suitable control marks places within the image at step **238** swath with highest ink content is further analyzed for sections having clusters of inked pixels of sufficient size for marks placement.

[0066] Distribution of image on substrate position control marks along and across printed swath in a way that enables relatively smooth continuous corrective data shift between the nozzles of print head **174** definition of which takes place at step **240**. The processed swath is printed simultaneously with image position control marks at step **242**. The process continues in a similar way for the next swath.

[0067] Distribution of image positions control marks along and across printed swath in a way that enables relatively smooth continuous corrective data shift between the nozzles of print head **174** within a single color (ink) may not always be possible. Highlight print areas may have not enough dense clusters for proper control marks positioning. In such extreme cases image on substrate position control marks may be placed in more than one printing color (ink).

[0068] Alternatively image position control marks may be printed by ink invisible to human eye, but easy detectable by image position detection means. Such marks may be printed in any location on the substrate and no special image processing is required. Printing control marks by ink invisible to human eyes requires however, an additional print head and increases the cost of the machine.

[0069] Image position control marks provide an effective tool for image position control. Monitoring the substrate position and shifting the data accordingly may achieve similar results. Figure 7A is a schematic illustrations of an inkjet printer constructed in accordance with an additional exemplary embodiment of the present invention. Printer of figure 7A is similar in structure to the printer of figure 5, except that image position sensors **180** have been replaced by non-contact substrate poison detection means **250**. Non-contact substrate position detection means **250** may be optical mouse type sensors such as ADNS – 2051 commercially available from Agilent Technologies, Inc. Palo Alto, CA 94303 U.S.A., or other similar sensors. Substrate position detection means **250** detect distortions, schematically shown by phantom line **254**, caused by wide format flexible substrates movement. Substrate position detection means **250** are in communication with control computer **114** that receives substrate distortion coordinates and shifts accordingly the data to be printed between the inner nozzles section and peripheral nozzles section. The continuous corrective data shift compensates for deformations and errors caused by wide format flexible substrate movement and reduces visible micro banding effects.

[0070] Wide format flexible substrate deformations, as shown in figure 7B by phantom lines **254** and **264**, are non-homogeneous along the printed swath. There may be instances in which the edges of substrate **108** are deformed, but central section of substrate **108** marked by phantom line **260** is not deformed. A second set of substrate position detection means **250'** disposed in a position allowing monitoring of the lower part of printed swath providing a more accurate correction value and accordingly the shift of data between inner and peripheral sections of nozzles of print head **174**. A variety of signal processing methods that are per-se not part of the invention may be used to process the position signals provided by substrate position detectors **250** and **250'**.

[0071] In an alternative embodiment non-contact substrate position detection means **250** may be replaced by contact substrate position detection means such as metering rollers that are in permanent contact with substrate **108**. Figure 8 shows such a metering roller **280** contacting substrate **108**. In order to avoid any roller slippage the contact surface of roller **280** has an abrasive type coating **284**. Roller **280** typically

has certain preload and it is desirable, but not necessary to have some type of back support surface **288** that facilitates the metering process.

[0072] Although the exemplary embodiments illustrate so-called micro banding artifacts correction, or correction of artifacts between the successive scans within the same print swath, the method is applicable to corrections of the macro banding artifacts or artifacts between two relatively wide printed swaths.

[0073] Prints printed by the disclosed printer produce images of significantly improved quality, as compared to existing printers. They do not exhibit micro banding effects and have reduced macro-banding effects. The width of printed substrate may be further increased without damaging print quality.

[0074] The above disclosure is intended as merely exemplary, and not to limit the scope of the invention, which is to be determined by reference to the appended claims.

What is claimed is:

1. A method of multi pass inkjet printing on wide format flexible substrates, comprising steps of:

   a. providing an inkjet printer having a print head, a substrate, and a control computer;

      i) said print head further having ink ejecting nozzles distributed along said width (W) and split virtually into inner section nozzles and peripheral sections nozzles;

   b. moving said substrate in first printing direction and scanning said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

c. printing an image on said substrate by print head wide (W) swaths and filing said printed swath by reciprocating scanning movement of said print head in second direction;

wherein said multi pass inkjet printing is performed by shifting drop ejection nozzles position from inner section nozzles to peripheral nozzles said shift in drop ejection nozzles position in first direction compensates for deformations caused by wide format flexible substrate movement in said first printing direction.

2. A method of ink jet printing on wide format flexible substrates, as in claim 1 wherein said control computer controls the step of selective shift of ink ejecting nozzles position in said first direction.

3. A method of inkjet printing on wide format flexible substrates, comprising steps of:

a. providing an inkjet printer having a print head, a substrate, image on substrate position detection means, and a control computer;

i) said print head further having ink ejecting nozzles distributed along said width (W) and split virtually into inner section nozzles and peripheral sections nozzles;

b. moving said substrate in first printing direction and scanning said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

c. printing simultaneously with an image a series of image position control marks, said control marks defining actual image position of said substrate;

d. detecting by said substrate position detecting means said control marks coordinates and providing said control marks coordinates to said control computer;

e. calculating the deviation value of said actual wide format flexible substrate position from the desired (target) substrate position, and

wherein said inkjet printing is performed by correcting said wide format flexible substrate position error by shifting ink ejecting nozzles position along print head width generally parallel to said first printing direction in accordance with said deviation value.

4. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks positions said marks outside the image area.

5. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks positions said marks within the image area.

6. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks positions said marks in places that will be overprinted by ink of the same color.

7. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of printing image position control marks is performed with ink visible to human eyes.

8. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks printing is performed with ink invisible to human eyes.

9. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of defining the direction of selective shift of ink ejecting nozzles position along print head width generally parallel to said first direction is derived from actual printed swath on substrate position.

10. An ink jet printing apparatus for printing on wide format flexible substrates, comprising:

   a. a substrate and a mechanism for moving said substrate, a print head and a mechanism for moving said print head, substrate position detecting means, and a control computer;

      ii) said print head further having ink ejecting nozzles distributed along said width (W) split virtually into inner section nozzles and peripheral sections nozzles;

   b. said substrate moving mechanism moves said substrate in first printing direction and said print head moving mechanism scans said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

   c. said print head prints simultaneously an image and a series of image on substrate position control marks, coordinates of said marks provide information on actual position of said image on substrate;

   d. said image on substrate position detecting means, detect said image on substrate position control marks coordinates defining actual image on substrate position and communicate said coordinates to said control computer;

e. said control computer calculates the deviation of said actual image on substrate position from the theoretical (target) image on substrate position, and

whereby said inkjet printing is performed by shifting ink ejecting nozzles position along print head width generally parallel to said first printing direction in accordance with said deviation value.

11. An ink jet printing apparatus for printing on wide format flexible substrates, as in claim 10 and where substrate detection means are one of a group of photodiode, position detector, video camera.

12. A method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by selective shift of ink ejecting nozzles position on said deviation value and where said selective shift of ink ejecting nozzles position is performed in the same direction as said wide format flexible substrate moves.

13. A method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

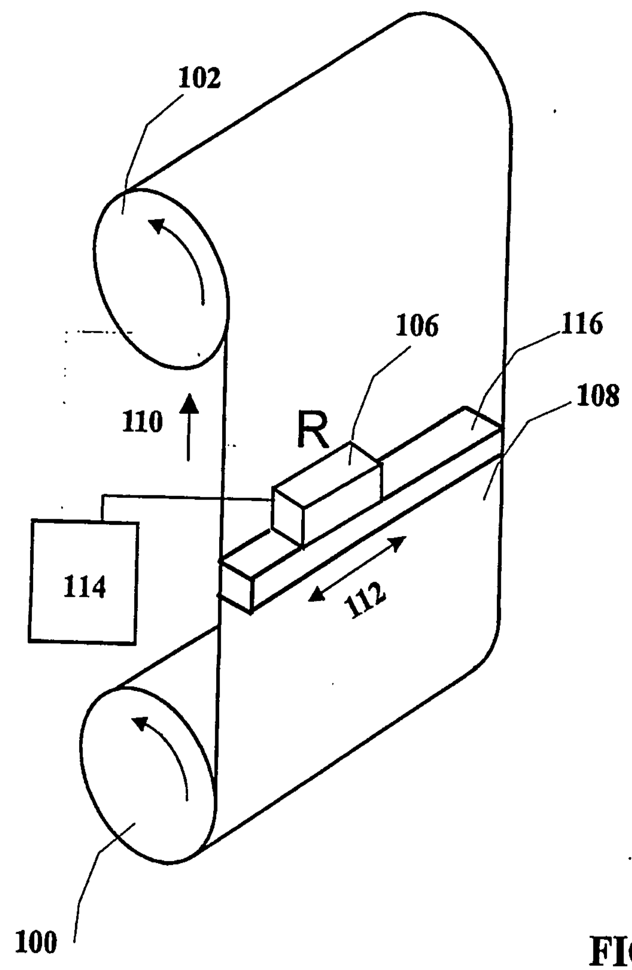

FIG. 1

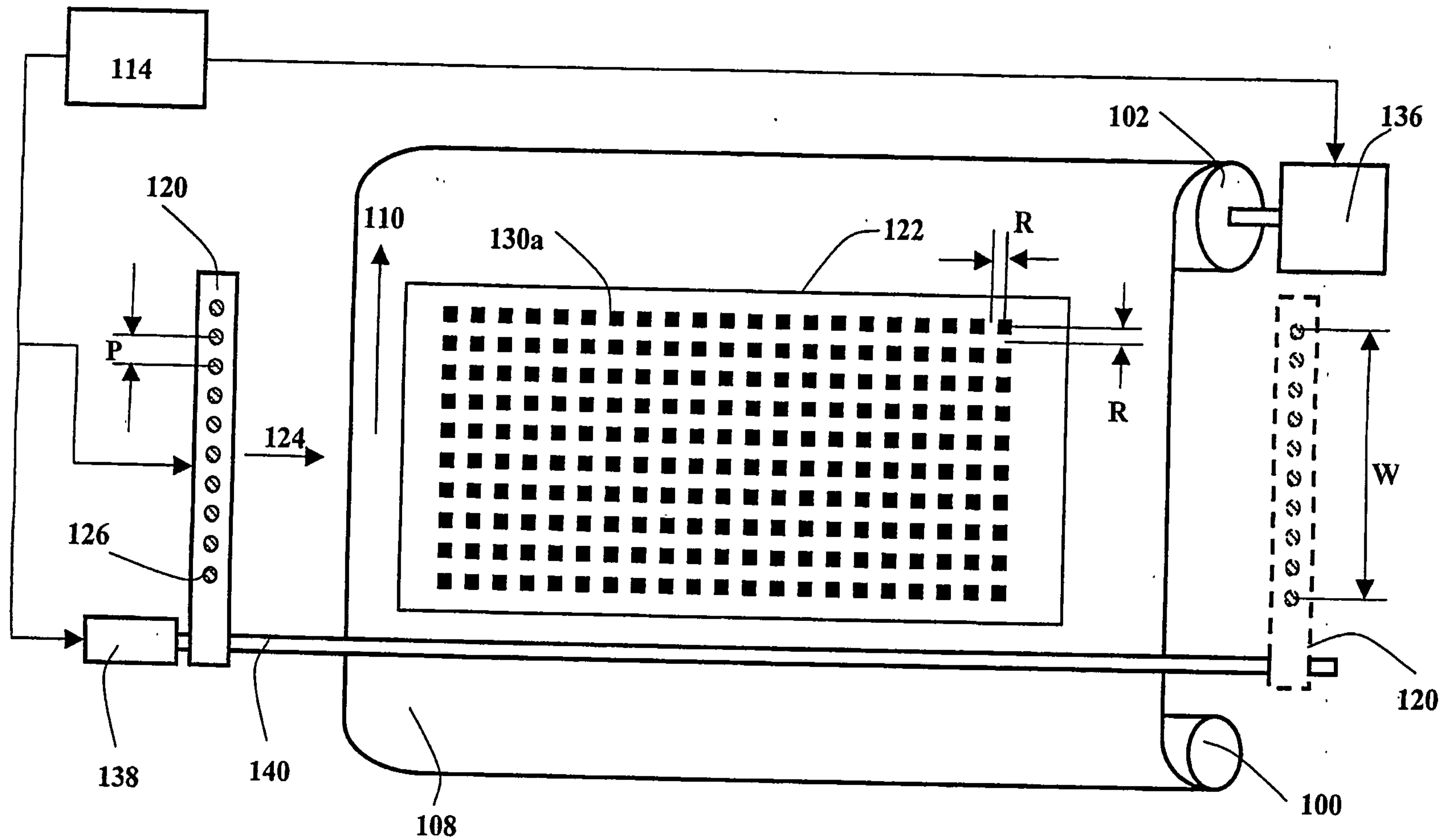

FIG. 2A. PRIOR ART

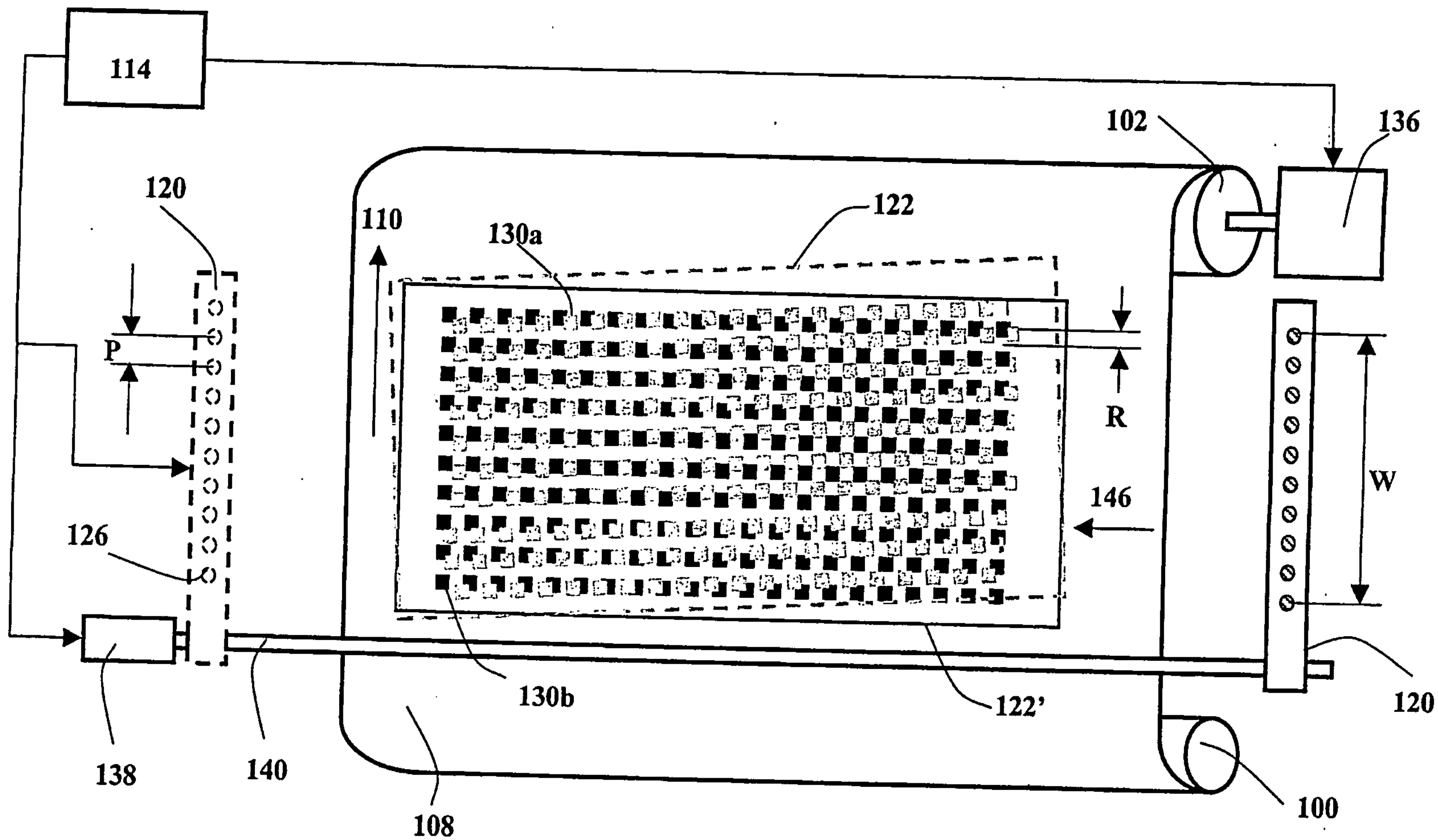

FIG. 2B. PRIOR ART

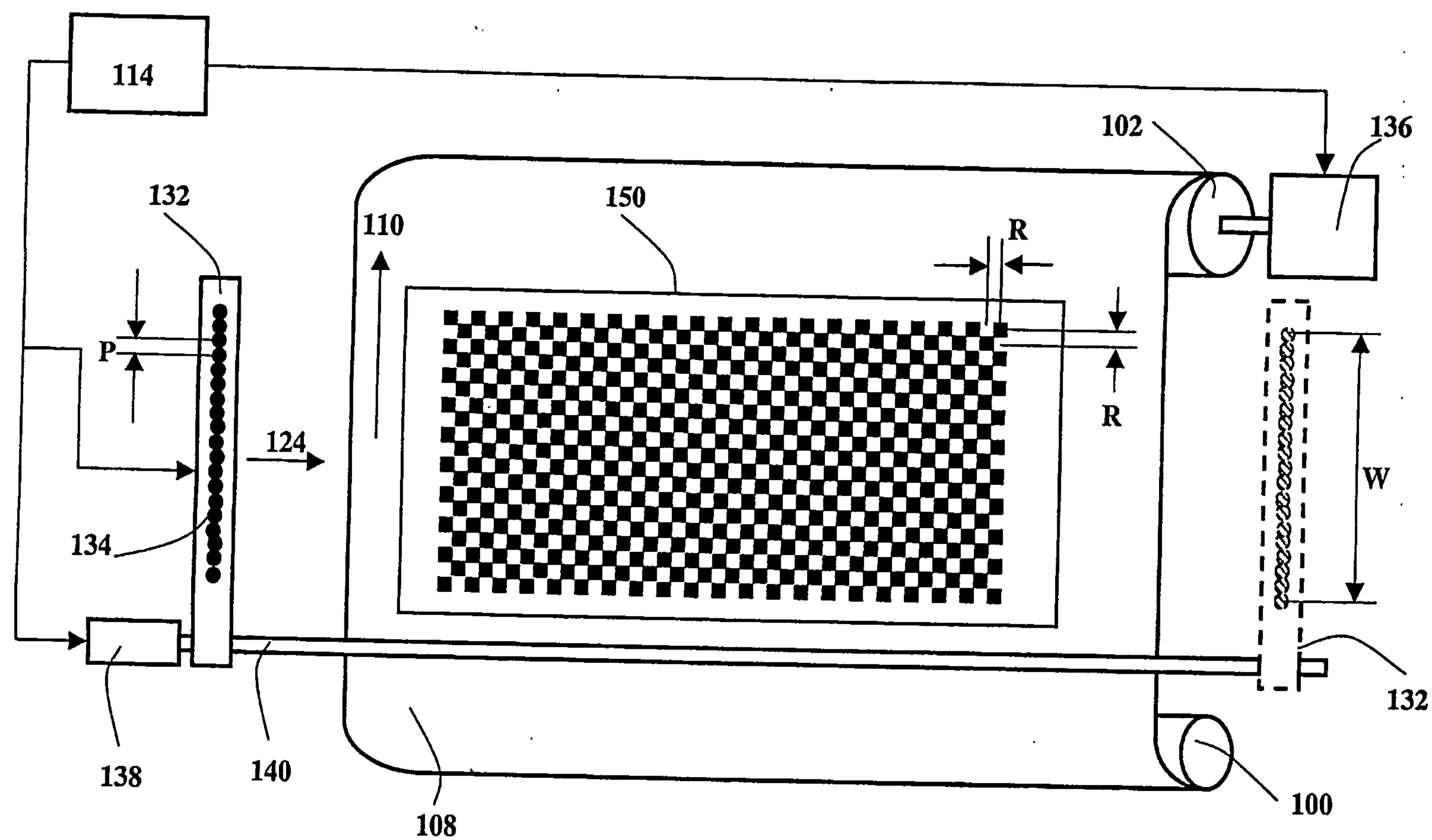

FIG. 3.

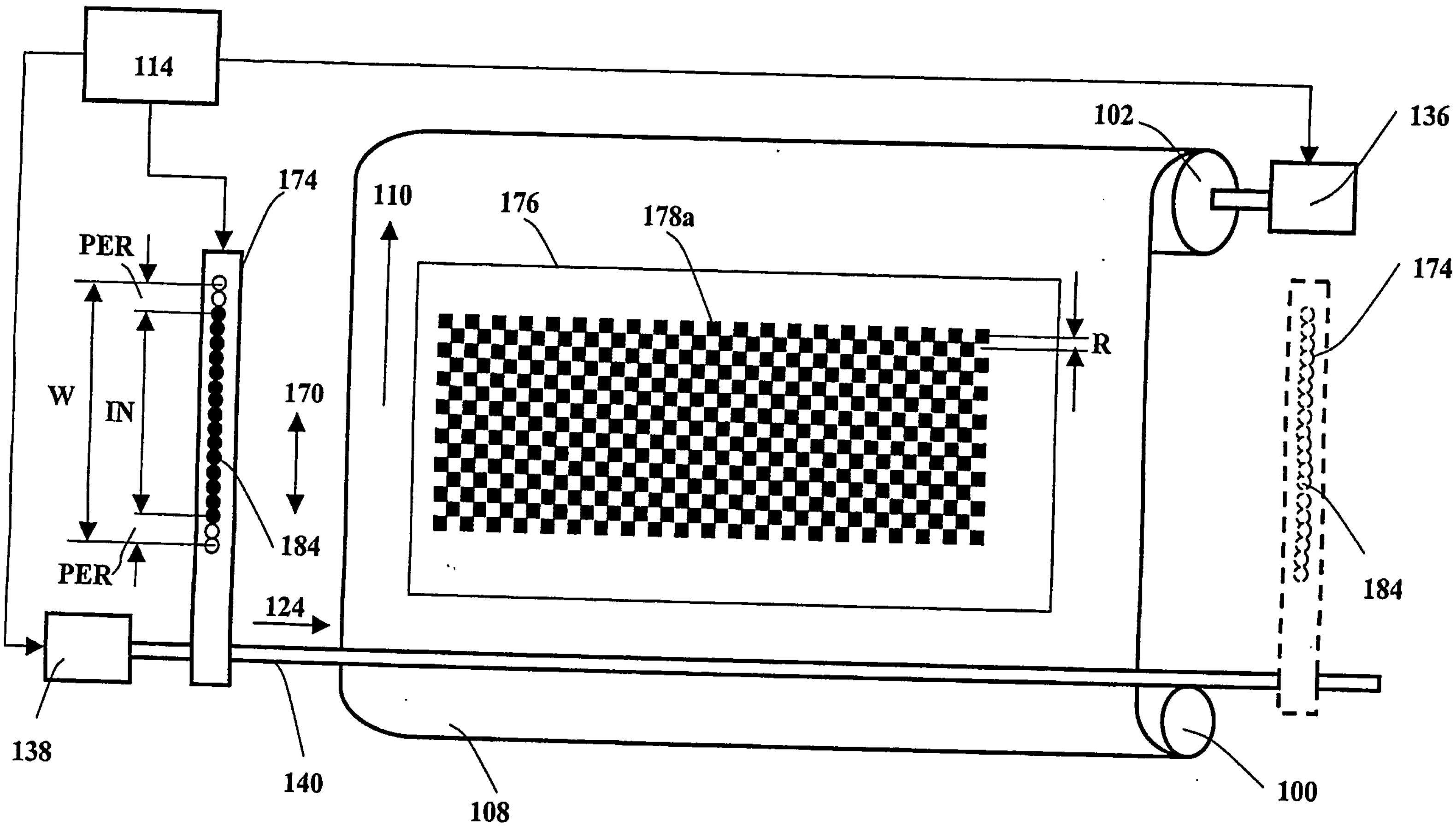
114
102
136
174
110
176
178a
PER
R
W
IN
170
184
PER
124
138
140
108
100

FIG. 4A

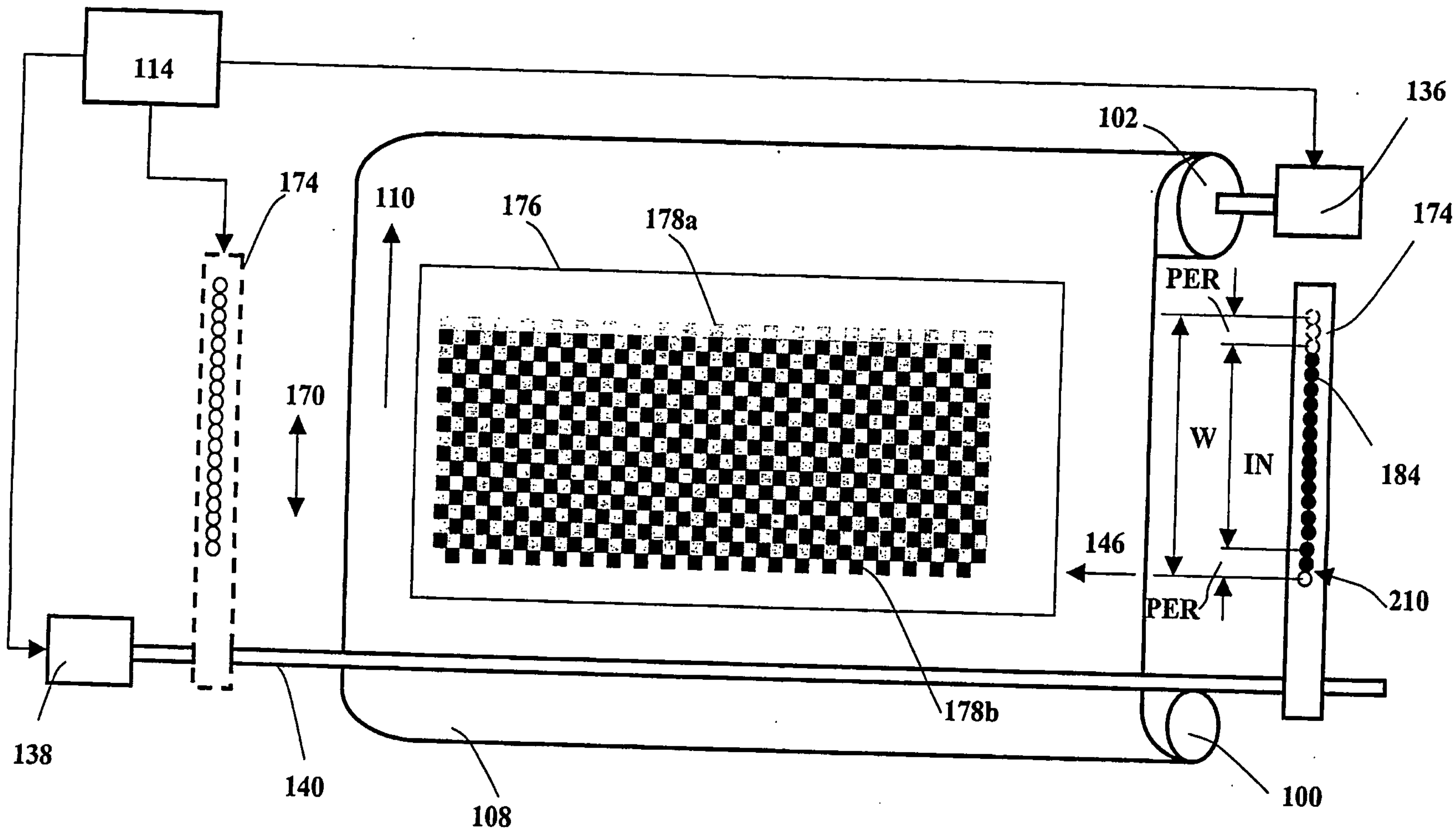
114
136
102
174
110
176
178a
174
170
PER
W
IN
184
146
210
PER
138
140
178b
108
100

FIG. 4B

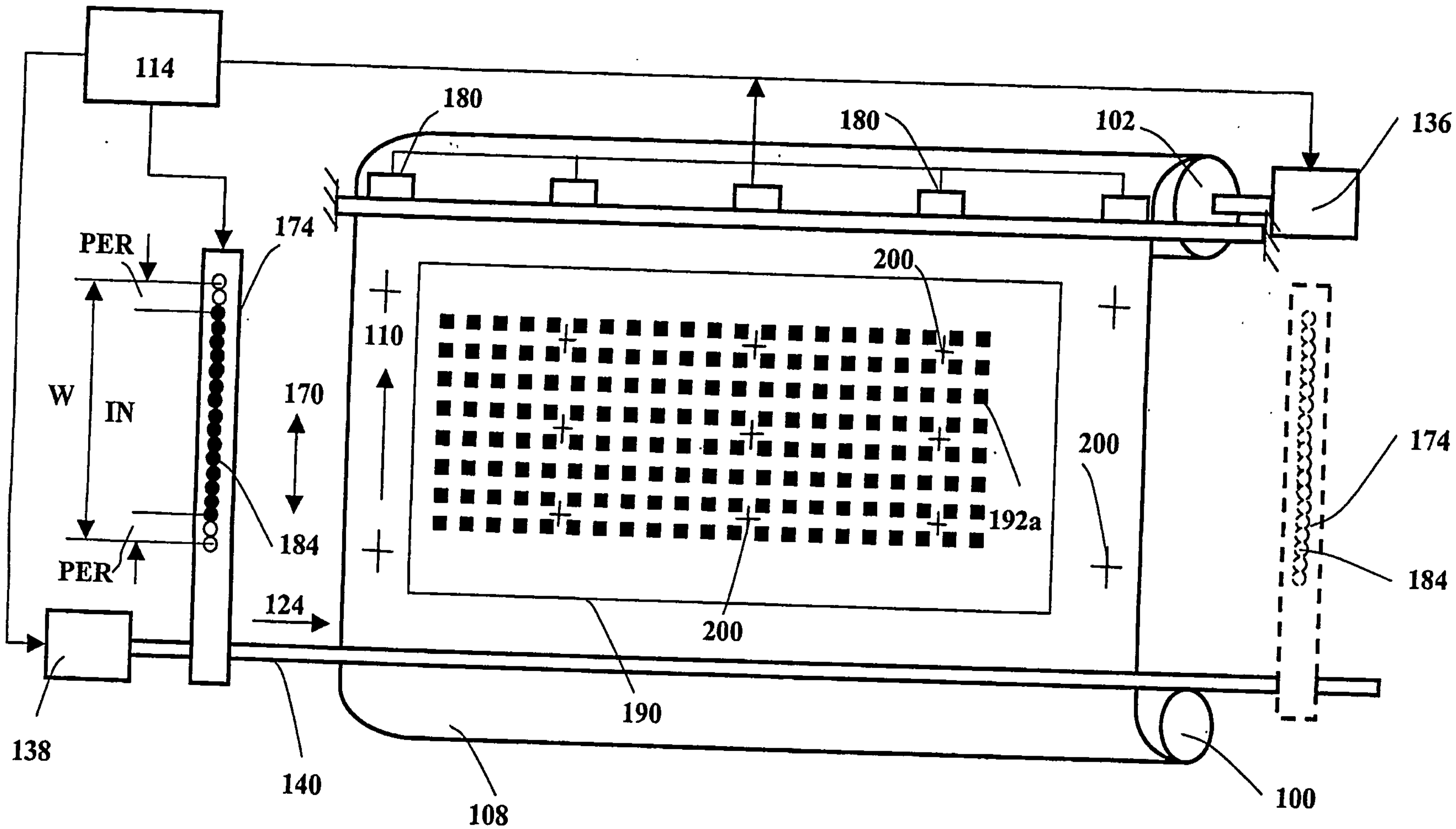
114
180
180
102
136
174
PER
200
110
W
IN
170
200
192a
174
184
PER
124
200
184
138
190
140
108
100

FIG. 5A

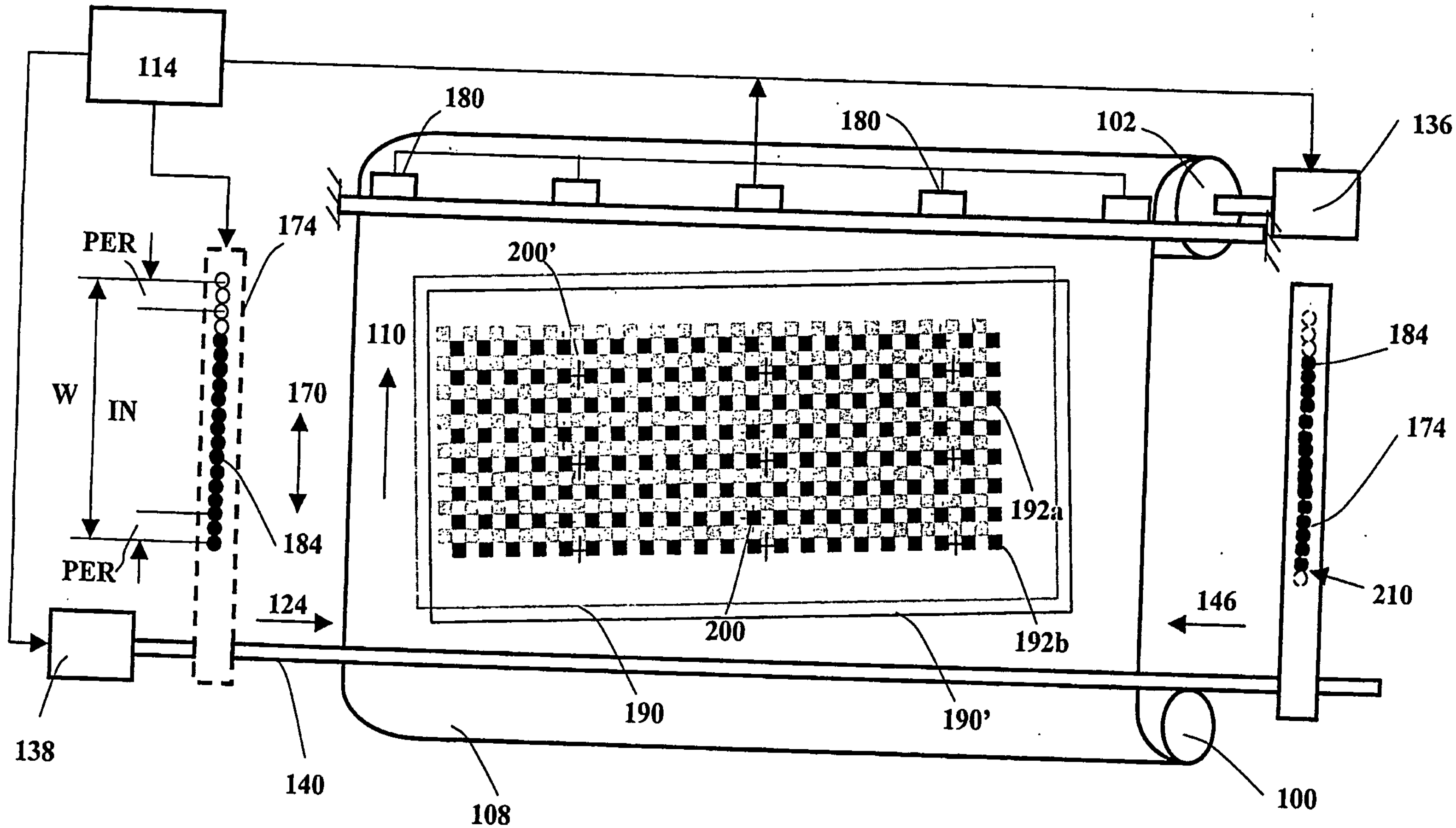
114
180
180
102
136
174
PER
W
IN
PER
184
170
110
200'
184
174
192a
192b
210
146
124
200
138
140
190
190'
108
100

FIG. 5B

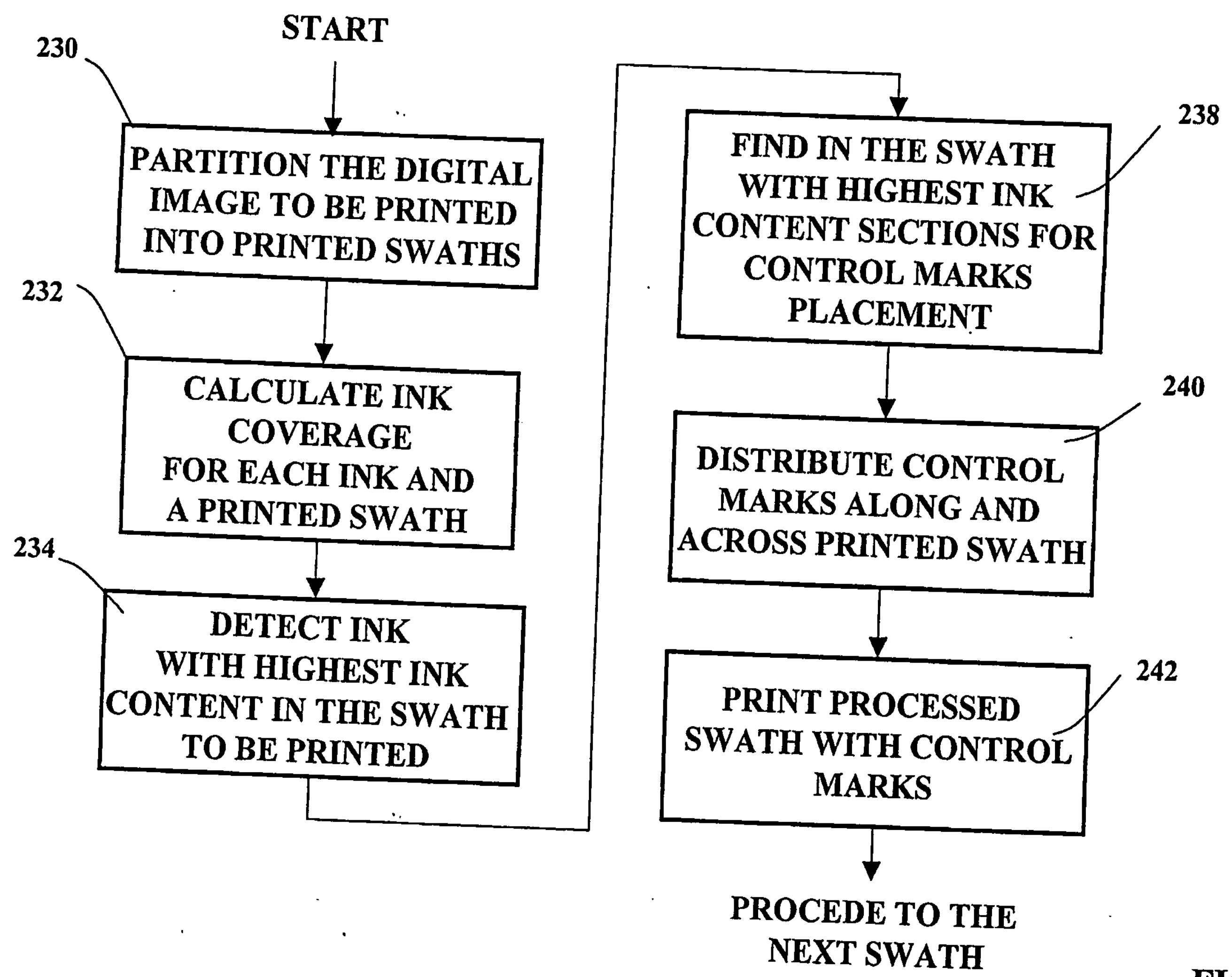
START
230
PARTITION THE DIGITAL IMAGE TO BE PRINTED INTO PRINTED SWATHS
232
CALCULATE INK COVERAGE FOR EACH INK AND A PRINTED SWATH
234
DETECT INK WITH HIGHEST INK CONTENT IN THE SWATH TO BE PRINTED
238
FIND IN THE SWATH WITH HIGHEST INK CONTENT SECTIONS FOR CONTROL MARKS PLACEMENT
240
DISTRIBUTE CONTROL MARKS ALONG AND ACROSS PRINTED SWATH
242
PRINT PROCESSED SWATH WITH CONTROL MARKS
PROCEDE TO THE NEXT SWATH

FIG. 6.

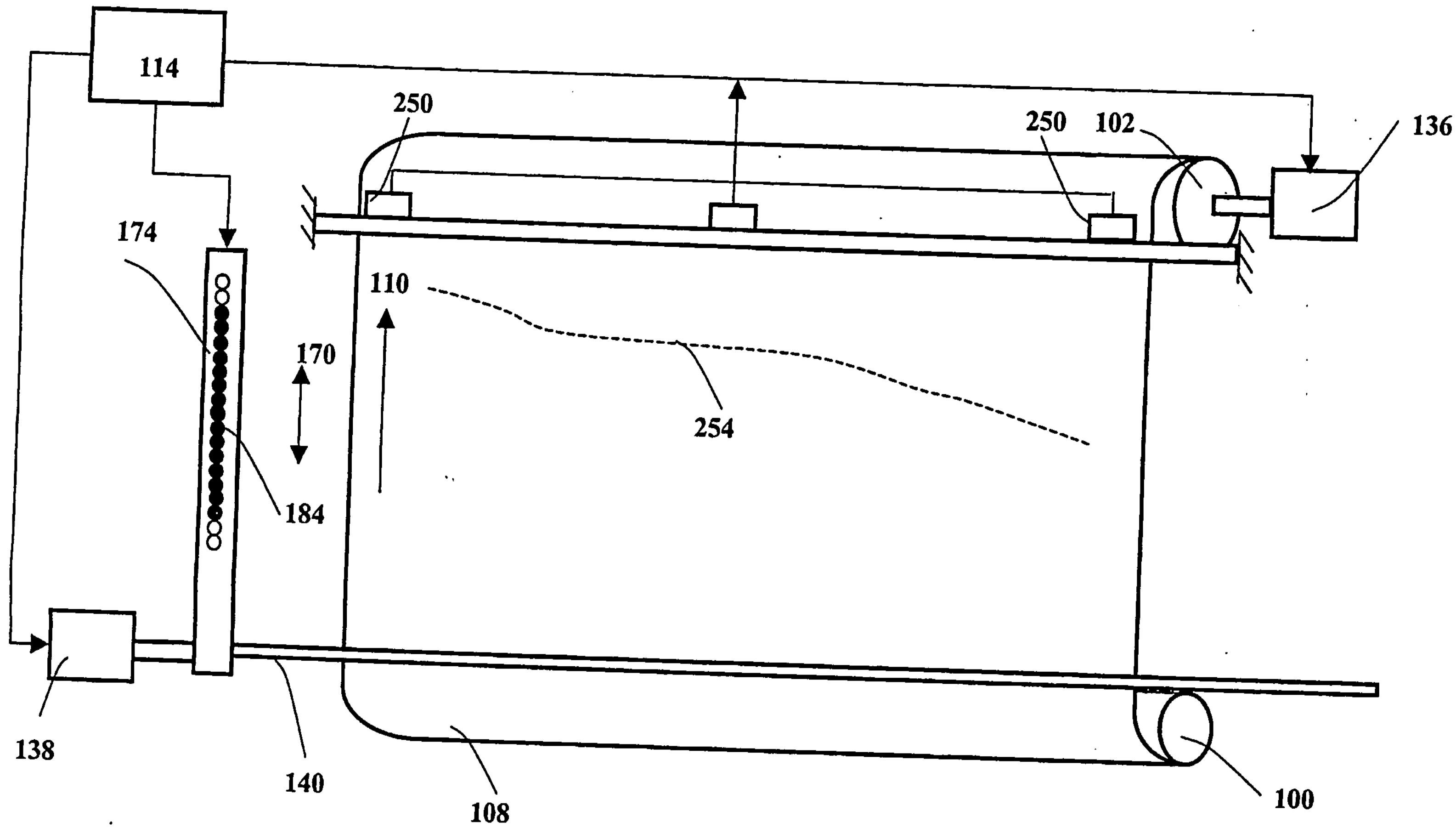

FIG. 7A

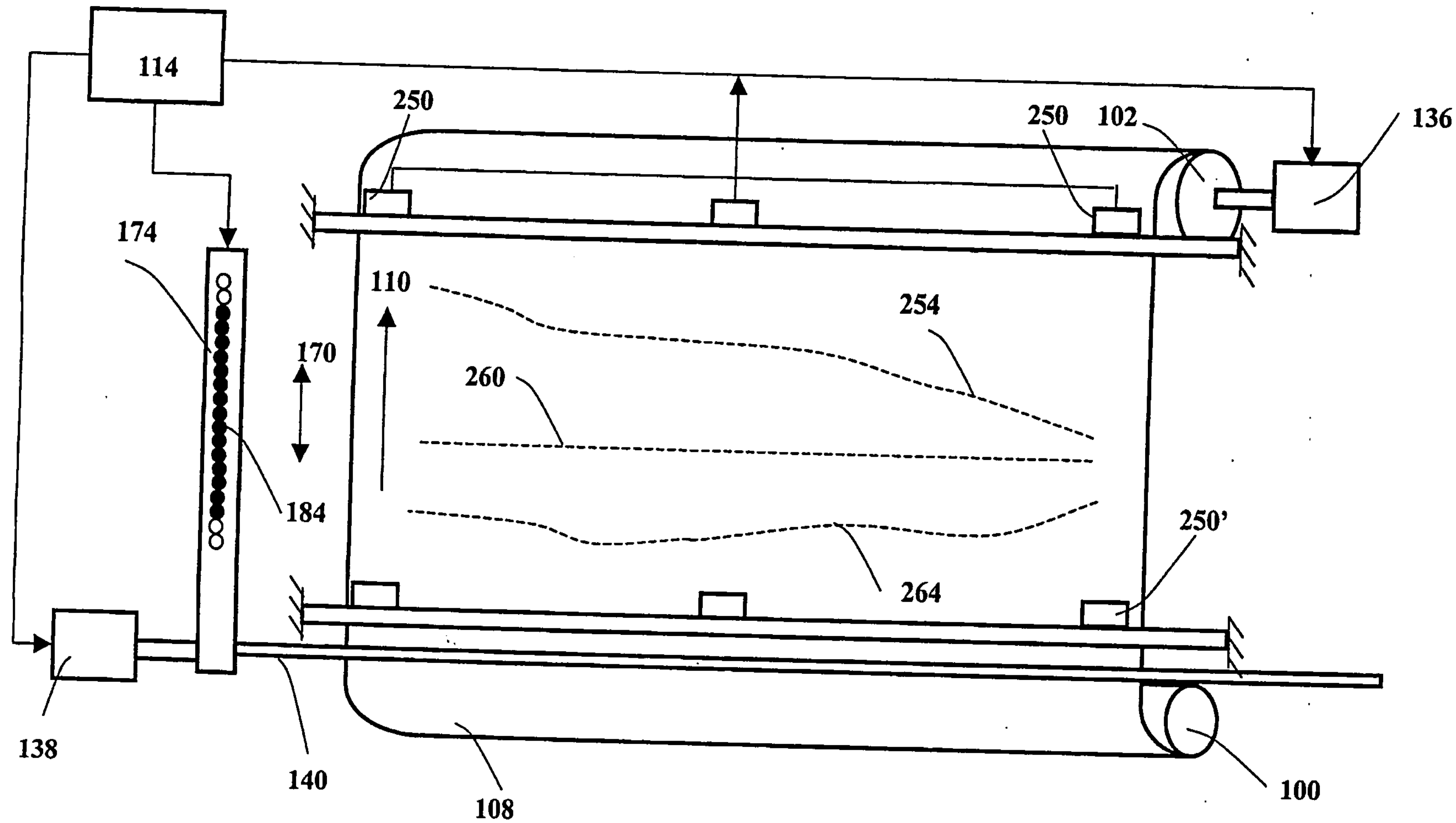
114
250
250
102
136
174
110
170
254
260
184
250'
264
138
140
108
100

FIG. 7B

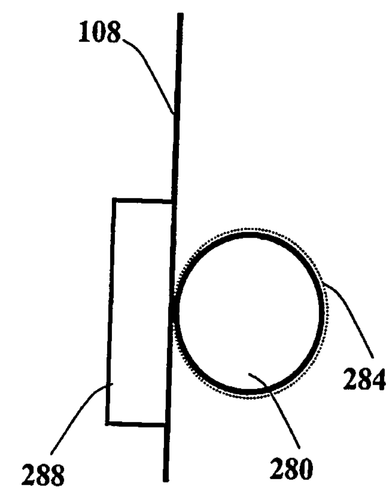

FIG. 8.